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The distribution of benthic macroflora in the Swan River estuary, Western Australia

by Bruce M. Allender
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Botany Department, Monash University, Clayton, Vic., 3168

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Abstract

A survey of 53 of the most common benthic plants in the Swan River estuary shows the total number of species and their vertical distribution becomes smaller, while the proportion of chlorophycean species becomes larger, upstream from the mouth. Rapid and thorough freshwater flushing of the estuary in winter (June-August) results in a considerable decrease in species numbers and the survival of a few tolerant species, with rapid recolonization of the estuary when saline conditions return. The large number of algal species present suggests that pollution effects are low.

Introduction

In contrast with the estuaries of Europe and North America, the benthic macroflora of Australian estuaries has received very little ecological attention (Bayly 1975, Ducker, Brown and Calder 1977). In the case of the Swan River estuary, only brief species lists are provided by Thompson (1946) and Royce (1955). The recent book by Riggert (1978) provides an excellent account of the natural history of the Swan River estuary and contains a brief descriptive overview of the benthic flora.

This study provides data on seasonal, horizontal and vertical distribution of the macroflora as a baseline for future studies of changes in the flora of the Swan River estuary. The distribution of the Swan River estuary flora is compared with that of northern hemisphere estuaries, especially with a view to using the benthic plants as indices of pollution and other environmental disturbances.

Methods

The species of benthic multicellular plants of the estuary (including the diatom *Melosira moniliformis*) were collected as scrapings from all substrates (including sand, rock, wood, debris, shell fish) from the shoreline out to the limits of the photic zone at ten sites (Fig. 1) at 3-weekly intervals during 1968. The upper and lower depth limits of the plants were recorded, together with surface water temperatures (mercury thermometer) and salinities (conductivity meter). Tide level data were obtained from the Western Australian Public Works Department tide gauge near station 7 (Fig. 1), and from the Fremantle Port Authority gauge at the mouth of the estuary.

The upper limit of the study area was arbitrarily set at the junction of the Swan and Helena Rivers where the salinity was no greater than 5‰ and beyond which only 1-2 species of benthic algae occurred. The distribution of macroflora in the Canning River (stations 7A and 8A) was similar to that of the major arm of the estuary and will not be considered here.

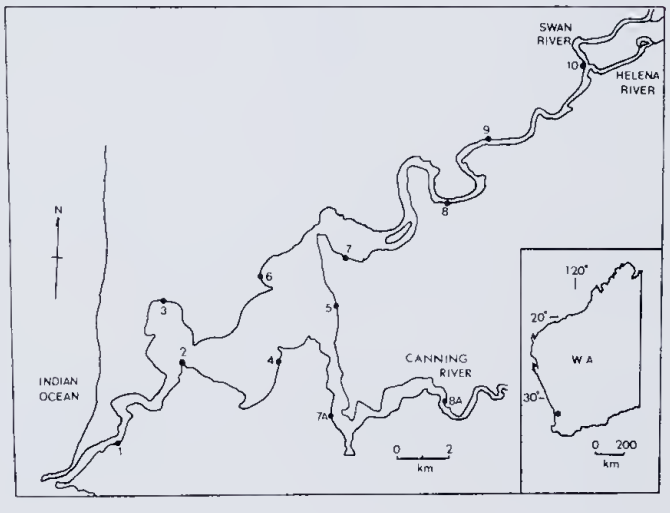

Figure 1.—Map of the Swan River estuary showing sampling stations.

Results

Hydrology

The hydrology of the Swan River estuary has been fully documented by Rochford (1951) and Spencer (1956). The seasonal phases of temperature and salinity were monitored during the study period to allow correlations with the distribution of the benthic flora. The summer-autumn phase was marine-dominated upstream to station 7 (Fig. 2), with salinity decreasing and water temperature increasing further upstream. After winter rainfall and fresh-

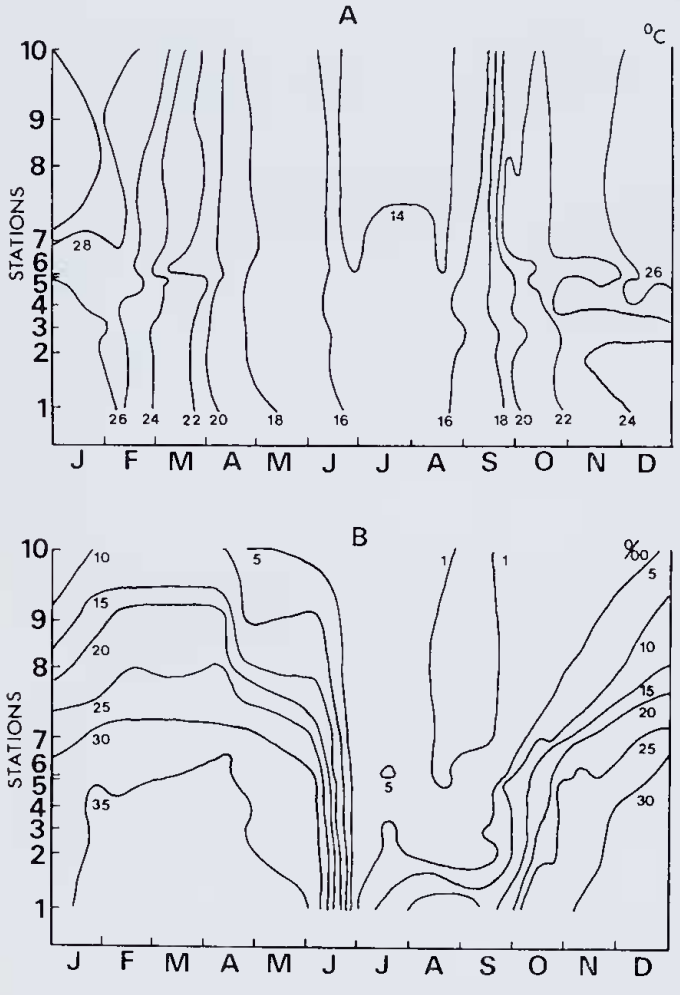

Figure 2.—Water temperature and salinity isopleths of the Swan River estuary. The stations are from Figure 1 and are scaled in distance upstream from the estuary mouth. A.—surface isotherms (°C), B.—surface isohalines (°/oo).

water runoff, the winter-spring phase had a halocline with cool freshwater to 2-5 m depth and high turbidity throughout the estuary. The tidal amplitude of about 0.9 m at the estuary mouth gradually decreased upstream. The average high tide level during December and January (summer) was 0.3-0.4 m lower than during June and July (winter) because of the lower mean sea level and considerably reduced river flow in summer.

Benthic Flora

Sixty-nine benthic species were identified in the Swan River estuary, of which four were angiosperms. The distribution of 53 of the most common species was used for the ecological analysis. The species of *Enteromorpha, Cladophora* and several Cyanophyta have not been reliably determined, and this is a world-wide problem (apart from some regional studies). These species, of which there are probably 2-4 per genus, are grouped under the generic name. A preliminary species list is provided in the Appendix and voucher specimens are deposited at the University of Western Australia.

The maximum (usually summer) horizontal distributions of the species are shown in Table 3. The proportions of Phaeophyta and Rhodophyta to Chlorophyta species became smaller with increasing distance from the mouth of the estuary. The reduction in the total number of species upstream was highly correlated with surface salinity conditions (Table 1). During the late winter freshwater months, few species occurred throughout the estuary. The seasonal distributions of algae in the estuary (for example stations 1-3, Table 4) show that most species were annuals and that the time of reappearance of each species varied. The proportion of perennial to annual species increased upstream, and the same perennial species occurred throughout the estuary. The vertical distribution limits of the attached macroalgae decreased upstream (Table 2). The total vertical range was least in winter (July) with both the upper and lower vertical limits generally higher than in summer (January). Most species occurred on solid substrates (rock, wood, concrete), and many were also epiphytic. Eight species (Table 3) were found free-floating as well as attached. *Gracilaria verrucosa,* in particular, often occurred unattached and deeper than other attached algae.

Discussion

The overall distributional features of the macroflora of the Swan River estuary are in general agreement with previous northern hemisphere studies

Table 1

The number of benthic plant species in the Swan River estuary throughout the year, correlated with the salinity distribution for each month. The stations are shown in Figure 1.

Stations	Months											
	J	F	M	A	M	J	J	A	S	O	N	D
10	1	1	2	1	4	2	3	0	1	3	2	1
9	2	1	4	5	3	4	2	0	2	2	3	1
8	4	3	4	5	6	3	2	5	2	4	5	4
7	9	6	9	10	8	5	5	6	7	8	6	5
6	7	7	11	6	9	6	5	9	5	5	8	8
5	9	10	15	15	10	14	10	11	7	11	7	7
4	11	4	8	10	10	9	9	6	4	8	8	8
3	17	19	21	21	18	14	17	11	12	13	14	13
2	13	11	20	21	18	15	14	11	9	9	13	12
1	16	18	24	24	20	22	24	10	9	10	17	15
r	0·87	0·70	0·76	0·73	0·81	0·94	0·88	0·39	0·63	0·82	0·84	0·87

Table 2

The upper and lower vertical limits of macroalgae throaghoat the Swan River estaary in January (summer) and Jaly (winter). Figures are in cm, relative to mean sea level at Fremantle, Western Aastralia. The station nambers are shown in Figure 1.

	Stations	1	2	3	4	5	6	7	8	9	10
January	upper limit	+67	+70	+61	+58	+67	+73	+61	+40	+67	+67
	lower limit	−198	−46	−335	−61	−76	+27	+15	+15	+18	43
July	upper limit	+101	+91	+98	+79	+76	+73	+94	+70	+64	+70
	lower limit	−259	+12	−198	−15	−70	+46	+9	+64	+52	+64

Table 3

The maximum horizontal distribation of 53 selected benthic plants in the Swan River estuary, independent of the time of the year. The stations are shown in Figure 1. (*) denotes species occurring bot't free-floating and attached.

Species	Stations 0	1	2	3	4	5	6	7	8	9	10
Calothrix crustacea	=	=									
Rhizoclonium hookeri	=	=									
Bryopsis plumosa	=	=									
Porphyra lucasii	=	=									
Champia parvula	=	=									
Laurencia sp.	=	=									
Chondria dasyphylla?	=	=									
Spyridia filamentosa	=	=									
Melobesia membranacea	=	=									
Spirulina subtilissima	=	=	=	=	=	=	=	=			
Acetabularia calyculus	=	=	=	=	=	=	=	=			
Sphacelaria tribaloides	=	=	=	=	=	=	=	=			
Hypnea cervicornis	=	=	=	=	=	=	=	=			
Codium harveyi	=	=	=	=	=	=	=	=	=		
Cladophoropsis herpestica	=	=	=	=	=	=	=	=	=		
Oscillatoria spp.			=	=	=	=	=	=	=		
Dictyota dichotoma	=	=	=	=	=	=	=	=	=		
Calpomenia peregrina	=	=	=	=	=	=	=	=	=		
Bangia fuscoparparea	=	=	=	=	=	=	=	=	=		
Gelidiam pusillum	=	=	=	=	=	=	=	=	=		
Cystoseira trinodis			=	=	=	=	=	=	=		
Hormophysa triqaetra				=	=	=	=	=	=		
Grateloupia filicina	=	=	=	=	=	=	=	=	=		
Monospora australis	=	=	=	=	=	=	=	=	=		
Chaetomorpha area	=	=	=	=	=	=	=	=	=	=	=
**Chaetomorpha linum*	=	=	=	=	=	=	=	=	=	=	=
Ulva lactuca	=	=	=	=	=	=	=	=	=	=	=
Sphacelaria furcigera	=	=	=	=	=	=	=	=	=	=	=
Chondria tenuissima	=	=	=	=	=	=	=	=	=	=	=
Chondria sp.	=	=	=	=	=	=	=	=	=	=	=
**Ceramium cliftonianum*	=	=	=	=	=	=	=	=	=	=	=
Rosenvingea orientalis	=	=	=	=	=	=	=	=	=	=	=
Giffordia irregalaris	=	=	=	=	=	=	=	=	=	=	=
Goniotrichum alsidii	=	=	=	=	=	=	=	=	=	=	=
Ulothrix subflaccida	=	=	=	=	=	=	=	=	=	=	=
Callithamnion pasillum?	=	=	=	=	=	=	=	=	=	=	=
Microcoleus acutissimus			=	=	=	=	=	=	=		
Polysiphonia subtilissima	=	=	=	=	=	=	=	=	=	=	=
Giffordia mitchellae	=	=	=	=	=	=	=	=	=	=	=
Calothrix spp.			=	=	=	=	=	=	=	=	=
Cladophora spp.	=	=	=	=	=	=	=	=	=	=	=
Audoainella thuretii	=	=	=	=	=	=	=	=	=	=	=
Ulvaria oxyspernia	=	=	=	=	=	=	=	=	=	=	=
**Enteromorpha* spp.	=	=	=	=	=	=	=	=	=	=	=
**Ectocarpus silicalosas*	=	=	=	=	=	=	=	=	=	=	=
**Gracilaria verrucosa*	=	=	=	=	=	=	=	=	=	=	=
**Rhizoclonian riparium*	=	=	=	=	=	=	=	=	=	=	=
**Melosira moniliformis*	=	=	=	=	=	=	=	=	=	=	=
**Vaucheria* sp.			=	=	=	=	=	=	=	=	=
Lyngbya latea			=	=	=	=	=	=	=	=	=
Zostera macronata	=	=	=	=							
Halophila ovalis	=	=	=	=	=	=	=	=	=	=	=
Potamogeton pectinatus										=	=

Table 4

The seasonal distribution of benthic plants in the lower Swan River estuary (stations 1–3 in Figure 1).

(e.g. Conover 1958, den Hartog 1967, Mathieson and Fralick 1972, 1973, Kjeldsen and Phinney 1971), in that there are fewer and fewer species of essentially marine algae penetrating upstream from the estuary mouth. A causal relationship between species presence and salinity distribution in estuarine environments is supported by experimental evidence for the deleterious effects of freshwater upon the growth and metabolism of macroalgae (e.g. Gessner and Schramm 1971, Kjeldsen and Phinney 1971).

The marked two-phase hydrology of the Swan River estuary is reflected in the sudden winter decrease in the number of algal species and their populations in the estuary, an effect attributed to the rapid flushing of the estuary with cool, turbid freshwater from the Swan, Helena and Canning Rivers. Although a halocline persists through winter with saline water at depths greater than 2-5 m almost all the benthic flora is shallow water and within the freshwater zone (Table 2).

The seasonal reduction in species diversity in the Swan River estuary is not a feature of the northern hemisphere estuaries mentioned above. Consequently, the flora of the Swan River estuary may be categorized into either annual or perennial groups depending upon whether the plants survive the winter season. However some species (e.g. *Enteromorpha* spp. and *Cladophora* spp.) do not conveniently fit into either category as they are continuously represented by successive generations (the seasonal annual concept of Sears and Wilce 1975). There is the additional consideration of physiological races of species adapted to different conditions within the same estuary (Bolton 1977). These mechanisms of rapid population turnover and adaptation must increase the tolerance and distributional limits of some estuarine species. Most annual and perennial species repopulate rapidly with the return of saline conditions in summer. However variations in times of reappearance of the annual species suggests that there are differences in physiology or over-wintering strategy. For example, regrowth from persistent fragments may be faster than growth from spores.

The vertical distribution of estuarine algae has received little attention apart from that observed in the intertidal zone (den Hartog 1967) and in brackish water submergence in fjords (Gessner and Schramm 1971). In the Swan River estuary the reduced vertical ranges of attached macroalgae upstream and during the freshwater phase (Table 2) may be because the deep water species (e.g. *Monospora australis*, *Gelidium pusillum* and *Polysiphonia subtilissima*) cannot tolerate continuous exposure to low salinities, although increased turbidity in winter also may be involved.

The number of benthic species in estuaries apparently depends upon the penetration and duration of marine water in the estuaries. Estuaries with more than 70 algal species, for example Great Pond, Massachusetts (Conover 1958) and Great Bay, New Hampshire (Mathieson and Fralick 1972) are strongly marine influenced for most of the year. The Swan River estuary is probably in this category despite the severe freshwater influence of winter. Estuaries with a large freshwater influence or those affected by pollution contain fewer (about 30) species (Edwards 1972, Mathieson and Fralick 1973). With at least 65 species of benthic algae in the Swan River estuary, the system shows no evidence of pollution effects.

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Appendix

A preliminary list of benthic marine algae and seagrasses in the Swan River estuary. The main reference used in identification are also given.

Cyanophyta

Calothrix confervicola (Roth) C. Agardh? Fan 1956. Chapman 1956.
Calothrix crustacea Thuret Fan 1956. Chapman 1956.
Calothrix sp.
Lyngbya lutea (C. Agardh) Gomont Chapman 1956. Desikachary 1959.
Microcoleus acutissimus Gardner Chapman 1956. Desikachary 1959.
Oscillatoria amphibia C. Agardh Desikachary 1959.
Oscillatoria sp. 1.
Oscillatoria sp. 2.
Spirulina subtilissima Kuetzing Chapman 1956. Desikachary 1959.

Chlorophyta

Acetabularia calyculus Quoy et Gaimard Solms-Laubach 1895.
Bryopsis plumosa (Hudson) C. Agardh Chapman 1956.
Caulerpa racemosa (Forsskal) J. Agardh var. *laetevirens* Montagne) Wever van Bosse Cribb 1958.
Chaetomorpha aerea (Dillwyn) Kuetzing Chapman 1956.
Chaetomorpha linum (Mueller) Kuetzing Chapman 1956.
Cladophora albida (Hudson) Kuetzing? Soderstrom 1963.
Cladophora fascicularis (Mertens in C. Ag.) Kuetzing? Soderstrom 1963.
Cladophora flexuosa (Mueller) Kuetzing? Soderstrom 1963.
Cladophora harvey Womersley? Womersley 1956.
Cladophora laetevirens (Dillwyn) Kuetzing? Soderstrom 1963.
Cladophora sp.
Cladophoropsis herpestica (Montagne) Howe Cribb 1960.
Codium harveyi Silva Silva and Womersley 1956.
Enteromorpha ahlueriana Bliding? Bliding 1963.
Enteromorpha compressa (Linnaeus) Greville Bliding 1963.
Enteromorpha flexuosa (Wulfen ex Roth) J. Agardh? Bliding 1963.
Enteromorpha sp.
Rhizoclonium hookeri Kuetzing? Chapman 1956.
Rhizoclonium riparium (Roth) Harvey Chapman 1956. Bliding 1957.
Ulothrix subflaccida Wille Ramanathan 1964.
Ulothrix sp.
Ulva lactuca Linnaeus Chapman 1956.
Ulvaria oxysperma (Kuetzing) Bliding var. *oxysperma* Bliding Bliding 1968.

Phaeophyta

Colpomenia peregrina (Savageau) Hamel Clayton 1975.
Cystoseira trinodis (Forsskal) C. Agardh Papenfuss and Jensen 1967.
Dictyota dichotoma (Hudson) Lamouroux Lindauer Chapman and Aiken 1961.
Ectocarpus siliculosus (Dillwyn) Lyngbye Clayton 1974.
Giffordia mitchellae (Harvey) Hamel Clayton 1974.
Giffordia irregularis (Kuetzing) Joly Clayton 1974.
Hormophysa triquetra (C. Agardh) Kuetzing Papenfuss 1967.
Rosenvingea orientalis (J. Agardh) Boergesen Misra 1966.
Sphacelaria furcigera Kuetzing Misra 1966.
Sphacelaria tribuloides Meneghini Misra 1966.

Chrysophyta

Melosira moniliformis (Mueller) C. Agardh Cupp 1943.

Xanthophyta

Vaucheria sp.

Rhodophyta

Audouinella thuretii (Bornet) Woelkerling Woelkerling 1971.
Bangia fuscopurpurea (Dillwyn) Lyngbye Levring 1953.
Callithamnion pusillum Harvey? Harvey 1855.
Ceramium cliftoniaum J. Agardh Womersley 1978.
Champia parvula (C. Agardh) Harvey Reedman and Womersley 1976.
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